Galactaric acid and its Chemical (derived) Building Blocks

November 2018
Royal Cosun: facts and figures

- Started out as a sugar producing cooperative (1899)
  - Stakeholders: 9,500 farmers

- Cosun’s core competences:
  - Extraction and purification of biomass
  - Technology driven

- Royal Cosun in 2017:
  - 6 different business units
  - €2.1 billion turnover
  - ±10 million ton crops per year input
  - ±25 processing plants
  - ±4000 FTE
Royal Cosun: facts and figures

- Started out as a sugar producing cooperative (1899)
- Changed its strategy: Excelling in creating value from crops
Our state-of-the-art Innovation Center

- Completed in (Q2) 2017 → Strong focus on innovation and development
- ±120 FTE
  - Cosun Biobased Products (CBP) - New Business & Innovation
  - Cosun R&D
  - IRS
Cosun Biobased Products
Biobased innovation is in our DNA

❖ Cosun Biobased Products (CBP)
  ➢ Founded in 2010
    ✓ Part of the Royal Cosun group (€ 2.1 billion turnover)
  ➢ Biorefining of agricultural side streams
  ➢ Challenger of existing chemical suppliers with our ever expanding portfolio of biobased functional ingredients

❖ Key reasons for our success
  ➢ Track record of strategic collaborations with customers
  ➢ Backward integrated into farming industry → Security of supply
  ➢ Solid parent company with long term vision
  ➢ Deep understanding of customer needs
  ➢ Successful in scale up from project to manufacturing
Biorefining at CBP

Primary process

Grow

Harvest

Logistics

Process

Logistics

Sugar

Grow

Melasses
Sugar Beet Pulp

Step 1

Primary products
Arabinose
Cellulosic fiber
D-galacturonic acid
Etc.

Step 2

Bioconversion plant

Functional additives

Green gas

No waste
D-galacturonic acid and its derivates
Sugar beet derived molecules with unique functionalities
Backward integration within Cosun

1. On the land
   Sugar beet is sown in March and April.

2. Lifting and loading
   The harvest starts in September.

3. Transport
   Trucks transport the sugar beet to the factory.

4. The factory
   The processing of the sugar beet starts.

5. Determination of the sugar content
   The sugar beet is weighed and the sugar content is determined.

6. Purification of juice
   Minerals, salts and proteins are extracted from the raw juice.
   It now becomes thin juice with a sugar content of approximately 13%.

7. Boiling
   The thick juice is further concentrated into a thick syrup mixture.

8. Evaporation
   By evaporating the syrup (with steam), the thin juice thickens and the sugar content increases to approximately 70%.
   It now becomes thick juice.

9. Industrial clients
   The sugar is transported to clients in bulk trucks, among others.

10. Van Gils
    The sugar is marketed for consumers under the brand name Van Gils.

11. Storage
    The sugar is stored in sugar silos.

12. Centrifuging
    The centrifuge separates the crystal mixture into sugar crystals and syrup.

13. Juice extraction
    The sugar is extracted from the cells of the sugar beet.

14. Slicing of the sugar beet
    The sugar beet is sliced into thin strips.

15. Washing of the sugar beet
    The sugar beet is washed thoroughly and any soil is removed.

16. Soil received with the beets is used to raise the level of farmland, roads and dykes
    Molasses for fermentation and animal feed

17. Beet tails & wash water for green gas

18. Sugar Beet Pulp

19. CBP 2018 | 9
Sugar Beet Pulp (SBP) composition

Use of sugar beet

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (% w/w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4-8</td>
</tr>
<tr>
<td>Cellulose</td>
<td>22-26</td>
</tr>
<tr>
<td>Hemi-cellulose (arabanes)</td>
<td>22-26</td>
</tr>
<tr>
<td>Pectin</td>
<td>21-25</td>
</tr>
<tr>
<td>(Raw) proteins</td>
<td>6-10</td>
</tr>
<tr>
<td>Residuals</td>
<td>7-13</td>
</tr>
<tr>
<td>Soluble sugars</td>
<td>1-3</td>
</tr>
<tr>
<td>Lignin</td>
<td>0-3</td>
</tr>
<tr>
<td>Other</td>
<td>6-12</td>
</tr>
</tbody>
</table>

- Cosun SBP volume: > 1000 kT/annum
  - Currently sold as cattle feed (low contribution)

- Potential pectin volume: ...........
  - Find high value products (high contribution)
D-galacturonic acid extraction

- Extracted from pectins: Mild processing, biochemical extraction step
  - This process is executed on pilot scale (x-times)
  - D-galacturonic acid is available for sampling

Multiple grades available, purity up to > 99 %
Potential outlet for D-galacturonic acid:
Galactaric acid & Chemical Building Blocks

Cosun is comfortable with this reaction
Catalytic oxidation (patent pending)

Core competencies of Cosun

From biomass... ...to industry
Galactaric acid (Physical/chemical properties)

- Galactaric acid is a multifunctional (stable) building block for the chemical industry
  - Its Sodium salt is slightly soluble in water (circa. 3 wt%)
  - Acid groups can introduce new functionalities
  - Using nature’s full potential (OH’s)

- Unique properties:
  - Intermolecular hydrogen bonding’s results in strong crystalline structure
  - Structure provides good chelating/sequestering/buffering properties
  - Hetero atoms may result in unique properties
  - Symmetric molecule

![Galactaric acid structure](image)

Fig. 1. Atomic notation and thermal ellipsoids at 70% probability for galactaric acid at −147°.
Business opportunities (Galactaric acid)

- Cosun’s galactaric acid is produced from vegetable resources
  - Whereas the vast majority uses animal-based resources (galactose)
  - Cosun has a strong position on Galactaric acid (security of supply/patent pending on oxidation)

Galactaric acid

Note: Galactaric acid and its Sodium salt are available for sampling

1) Current market: Pharma/Personal Care
2) Galactaric acid/derivates as an additive
3) Galactaric acid for the production of Chemical Building Blocks
Chemical Building Blocks (CBB)

- Starting from Galactaric acid: Molecule weight increases during the process
  - GalX is using natures full potential (O-bounds)

- First scale up of GalX was done (>100 kg scale)
  - Commercial production of these CBB’s are out of Cosun’s scope

- GalX: Any amide/ester functionality can be introduced

Cosun is seeking partners

Galactaric acid → Di-ethylgalactarate → GalX → GalX derivatives
GalX (Research by universities)

- GalX can directly be used in polymers or polymer additives

- Research with Universities ’’Beets to Polymers project’’
  - Philips was one of the innovators
  - Transparent polymers with focus on high Tg were synthesized
  - Symmetric- and non aromatic polymers were produced (UV sensitive applications)

- GalX polymers showed good performance on Mw, PDI, Tg and E Modulus (Ductility, higher than commercial PolyAmides) Literature is published → FtO
- Ring-opening of GalX was patented by RUG (stable down to pH 1)

After polymerization: (Journal of Macromolecular Science, 50: 940 - 952, 2013, Cornelia Rosu)
Di-ethylgalactarate (Published literature)

- Literature details that di-ethyl galactarate can directly be used in polymerization reactions
- Di-ethyl galactarate is obtained via an esterification of Galacataric acid as mentioned in the previous slide

GalX derivatives  (Research/IP by Cosun Biobased Products)

- Research by Cosun Biobased Products:
  - Rigid building blocks were synthesized with improved Tg and reactivity compared to adipic acid
  - Oxygen atoms show a positive impact on the water solubility and the adsorption/adhesion (adhesion promoter) on surfaces
  - GalX molecules can open up new crosslinker functionalities. This may be a potential substitute for TGIC (which is under HSE pressure).

![C6-chains: with and without acetals](image)
- GalX with functional groups
- Adipic acid
(proven) **GalX derivatives**

**GalX allylamide**

**GalX amidol**

**GalX (CL) 1**

**GalX (CL) 2**

*IP: WO 2018/074926 Al*

*Shared research with DSM Coating Resins*
Primid vs GalX (CL)

- Primid is a well known crosslinker in the paint & coating industry
- GalX (CL) molecules have better water solubility compared to Primid

Primid XL-552

GalX (CL) 1

Primid QM-1260

GalX (CL) 2
Cosun Biobased Products - Your partner in biobased

Thank you for your attention